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THE EFFECTS OF DIFFERENT NITROGEN LEVELS ON SHOOT AND ROOT GROWTH OF HYBRID MAIZE GENOTYPES

Bülent Samancı

Akdeniz Üniversitesi, Ziraat Fakültesi, Tarla Bitkileri Bölümü

Antalya/Türkiye

A_stract: The effects of different nitrate concentrations (0, 0.05, 0.50, 0.75 and 1mol m^{-3} NO^{-}_{3}) on five maize hybrid genotypes were studied. The root and shoot growth depended on the genotype and concentration of NO^{-}_{3} in the nutrient solution. Increase of NO^{-}_{3} concentrations in the nutrient solution significantly reduced the root length to 24.34 cm whereas, weight did not increased accordingly. Highest root weight was obtained at 0.05 NO^{-}_{3} level. The genotypes reacted differently to the increase of NO^{-}_{3} concentration in the nutrient solution in shoot and root length but not with the weight. Root and shoot length and weight ratio as well as root/shoot ratios were independent from nitrogen concentration for the hybrid genotypes. With increasing nitrogen levels, cells in roots were also changed from 90 to 38, 5 μ in length and 15 to 8.12 μ in width. This study could be useful for screening hybrid genotypes for the efficient use of nitrogen.

Farklı Azot Miktarlarının Melez Mısır Genotiplerinin Kök ve Köküstü Büyümesine Etkisi

Özet: Farklı nitrat konsantrasyonların (0, 0.05, 0.50, 0.75 ve 1 mol m^{-3} NO^{-}_{3}) 5 hibrid mısır genotipi uzerine etkisi araştırılmıştır. Kök ve köküstü büyümesi genotiplere ve besi solusyonundaki NO^{-3}_{3} konsantrasyonuna bağlı olmuştur. Besi ortamındaki NO^{-}_{3} artması ortalama kök uzunluğunu 24.34 cm.'ye düşürmüş, buna karşılık ağırlık aynı oranda artmamıştır. En yüksek kök ağırlığı 0.05 NO^{-}_{3} konsantrasyonunda elde edilmiştir. Genotipler kök ve köküstü ağırlıkları bakımından aynı, uzunlukları bakımından ise solusyondaki NO^{-}_{3} konsantrasyonun artmasına karşı farklı tepki göstermiştir. Genotiplerin kök ve köküstü uzunluk ve ağırlıkları bakımından oranları ise azot konsantrasyonlarından bağımsız olmuştur. Konsantrasyonun artması ile köklerdeki hücre uzunluğu 90 dan 38.5 μ ve eni 15 den 8.12 μ 'a düşmüştür. Bu çalışma, azotun etkili kullanımı bakımından hibrid genotiplerinin seçilmesinde yardımcı olabilir.

Introduction

Screening of maize hybrids for ability to grow in low and high N supply can be one of the objectives in a breeding program. After test-crosses of many inbred lines to find heterosis in maize, one can also need to select the genotypes which are able to make better use of nitrogen. The success of such breeding programs would have the advantage of reducing the costs of fertilizer input and reduce the environmental problems related to higher nitrogen fertilization.

A growing plant tissue is a sink for both photosynthetic products and mineral nutrients. The balance between these two streams is still poorly understood (1). The relation between roots and shoots is very complex and the concentration of ions and energy-providing substrates as well as the level of hormones are important factors in a feedback system coordinating root activity with shoot demand (2).

Genotypical differences in nitrate efficiency of certain crop plants are well documented. Within a set of economically important tropical maize cultivars, considerable genetic variability for the traits such as grain yield at different N supply has been reported (3). The exploitation of this variability could be improved by developing early selection criteria. The purpose of this study was to evaluate the genotypes in seedling stage at different nitrogen levels and to understand the trend in the development of root and shoot growth.

Materials and Methods

Five maize hybrids of different genetic origin were used for the experiments. These hybrids (coded as 1 (49 X 12), 2 (54 X 65), 3 (35 X 123), 4 (13 X 178), 5 (87 X 51)) were obtained in Ceyhan Maize Breeding Program supported by Erciyes University Research Fund since 1993. Seeds from each hybrid were germinated in filter paper rolls, each containing 30 seeds and were placed vertically in 250 mL beakers with 100 mL distilled water, and maintained in complete darkness throughout the period of germination (72 hours) in growth chamber. When coleoptiles were 2-2.5 cm long, the seedlings were transferred to five glass containers (20X35X10 cm) each containing following nutrient solution: Macronutrients: (mol m^{-3}) N, 5.0; P, 0.5; K, 2.0; Ca, 1.0; Mg, 0.4; S, 1.5; as Ca $(NO_3)_2$, $Mg(NO_3)_2$, K_2SO_4, KH_2PO_4. Micronutrients (m mol m-3): Fe, 13.8; Mn, 3.6; Cu, 1.6; Zn, 1.5; B, 55.5; Mo, 1.0; as Fe EDTA, $MnSO_4$, $CuSO_4$, $ZnSO_4$, H_3PO_3 and $(NH_4)_6MO_7O_{24}$. Each treatment contained 0 as control (NO_3^- balanced by SO_4^{-2}), additional 0.05, 0.50, 0.75 and 1 mol m^{-3} NO^-_3 applied to five glass containers. Each genotype replicated with 3 times in each treatment. They were transferred to plant growth chamber with day-night temperature 25-18 °C, 18 h photoperied and 90 % humidity. After 30 days, containers were taken out from the growth chamber and root - shoot weight and length were measured and the ratios were calculated for each maize hybrids.

From the plants grown in the 0, 0.05 and 0.75 mol m^{-3} NO^-_3 solutions, 1 g of root samples (each from 1 cm away from the apex) from the hybrid 3 (35 X 123) were taken and put in solution containing 10 % bromic acid. When the cell walls are dissolved and separated from each other, their length and width were measured under the light microscope. The data from 20 cells in each treatment were taken and means for each variable were calculated.

Results and Discussion

Mean squares from the analysis of variance for the weight and length of root and shoot of five different maize hybrids grown in five different nitrogen solution are presented in Table 1. There were highly significant differences ($P < 0.05$) among different nitrogen levels for all the traits studied. The effects of increasing nitrate concentration on mean root and shoot weight and length are given in Table 2. In 0 nitrogen level (N1), mean root length for five genotypes was 57.50 cm; whereas, in 0.05 (N2), 0.50 (N3), 0.75 (N4), 1.00 (N5) mol m^{-3} nitrogen levels the root length gradually decreased to 35.26, 27.00, 29.84, and 24.34 cm , respectively. However, root weight did not increased as the root length increased. The mean root weight was 1.55 g in N1 solution and 2.26 g in N5 solution. Root / shoot ratio for length was 1.12 in 0 (N1) nitrogen level. However, equality of root and shoot growth changed in favor of shoot growth as the nitrogen level increased. Root / shoot ratio for weight was 0.83 in 0 (N1) nitrogen level and decreased to 0.35 in N3 solution and increased again to 0.65 as nitrogen increased. The hybrid genotypes differed in various aspects of root and shoot growth. Although there were significant differences in shoot and root length and weight among hybrids, the mean ratios, interestingly, did not changed. This gives rise to assumption that any nitrogen fertilization program in the field will not affect coordinated shoot and root growth and genotype will not have any affect on the ratio.

The effect of nitrogen levels of five different maize hybrids are shown in Fig 1 and 2. There is a general agreement that increasing nitrogen supply over wide range of concentrations enhances total plant growth (4). With increasing nitrogen levels, root length dramatically decreases and shoot length increases up to 0.5 mol m^{-3} then declines gradually. Root / shoot weight was at the maximum at 0.5 mol m^{-3} nitrogen solutions. However, at this maximum level, root / shoot ratio was at minimum and shoot growth is stimulated more than root growth leading to a negative correlation between nitrogen levels (up to 0.5 mol m^{-3} nitrogen) and root fraction.

It was interesting to note that the root length reached the highest level in 0 nitrogen level among all the other treatments. In order to understand the cellular mechanism of this result, root samples were taken from the hybrid 3 (35 X 123) and to measure cell sizes under the microscope and results were shown in Table 3. The cell length and width on 0 nitrogen level were 90 µ and 15 µ, respectively. In relation with nitrate concentration, those values were gradually declined to 38.50 µ and 8.12 µ in 1 nitrojen level. Depending on these results, the cell areas for the samples were calculated as 1350 µ2 being at the highest level. One might conclude that the higher root length seen in low NO^{-3} levels was due to increased cell length but not due to increased cell division.

References

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Table 2. The Mean values of root and shoot length and weight of five different maize hybrids grown in different NO^{-3} levels (0, 0.05, 0.50, 0.75 and 1 m mol m^{-3}) in nutrient culture.

Nitrogen levels ($mol\ m^{-3}$)	Hybrid	Root length (cm)	Shoot length (cm)	Root / Shoot	Root weight (g)	Shoot Weight (g)	Root / Shoot
0	1	69.70	50.70	1.38	1.19	1.50	0.80
	2	64.30	56.00	1.17	2.43	2.24	1.08
	3	51.50	53.50	0.97	1.52	1.84	0.85
	4	64.70	62.00	1.04	1.94	2.73	0.70
	5	37.30	36.00	1.05	0.77	1.02	0.76
X		57.50	51.64	1.12	1.55	1.86	0.83
0.05	1	33.30	55.70	0.60	1.50	3.14	0.48
	2	37.70	67.30	0.56	3.38	6.49	0.52
	3	35.70	52.30	0.68	1.85	3.76	0.51
	4	39.00	65.00	0.60	2.86	4.59	0.62
	5	31.00	47.70	0.65	1.37	2.88	0.50
X		35.26	57.60	0.61	2.19	4.17	0.52
0.50	1	25.70	74.00	0.35	1.81	6.69	0.28
	2	30.00	78.30	0.38	4.59	13.00	0.35
	3	31.30	86.70	0.36	3.81	11.50	0.35
	4	27.30	75.30	0.36	2.93	7.73	0.38
	5	20.70	53.00	0.39	1.50	3.68	0.41
X		27.00	73.46	0.36	2.92	8.52	0.35
0.75	1	30.00	76.00	0.40	2.31	6.38	0.36
	2	33.70	74.30	0.45	3.68	8.79	0.42
	3	30.00	72.70	0.41	2.56	7.63	0.35
	4	29.20	71.00	0.41	3.11	6.77	0.47
	5	26.30	52.50	0.51	1.12	2.58	0.44
X		29.84	69.30	0.43	2.55	6.43	0.40
1.00	1	22.00	70.70	0.31	2.45	4.60	0.51
	2	31.00	62.80	0.49	3.11	6.28	0.50
	3	27.30	57.70	0.47	1.92	3.56	0.54
	4	25.70	58.30	0.44	2.67	3.25	0.87
	5	15.70	34.20	0.50	1.15	1.60	0.86
X		24.34	56.74	0.44	2.26	3.85	0.65
Lsd		9.45	10.28	0.18	1.36	3.71	0.22

Table 3. The Effect of different nitrogen levels on the mean values of root cell sizes of maize hybrid 3 (35 X 123).

Nitrogen levels ($m\ mol^{-3}$)	Cell length (μ)	Cell width (μ)	Cell size (μ^2)
0	90.00	15.00	1350.00
0.05	48.50	11.26	546.11
0.50	41.70	9.53	397.40
0.75	38.10	8.90	339.09
1	38.50	8.12	312.62

Table 1. The mean squares from analysis of variance for root and shoot length and weight of five different maize hybrids grown in different NO^{-3} (0, 0.05, 0.50, 0.75 and 1 m mol m^{-3}) levels in nutrient culture.

Source	df	Root Length	Shoot Length	Root / Shoot	Root weight	Shoot weight	Root / Shoot
Replication	2	45.67ns	65.69 ns	0.01ns	1.88ns	7.59ns	0.008ns
Treatment	24						
Nitrogen (N)	4	2664.48**	1271.32**	1.42**	3.78**	98.20**	0.52**
Hybrid (H)	4	382.59**	1388.64**	0.006ns	10.90**	49.67**	0.019ns
N X H	16	85.01**	100.27**	0.025*	0.56ns	6.33ns	0.020*
Error	48	33.23	39.54	0.012	0.69	5.14	0.007
Total	74						

ns= non-significant
*, ** significant at 0.05 and 0.01 probability levels, respectively.

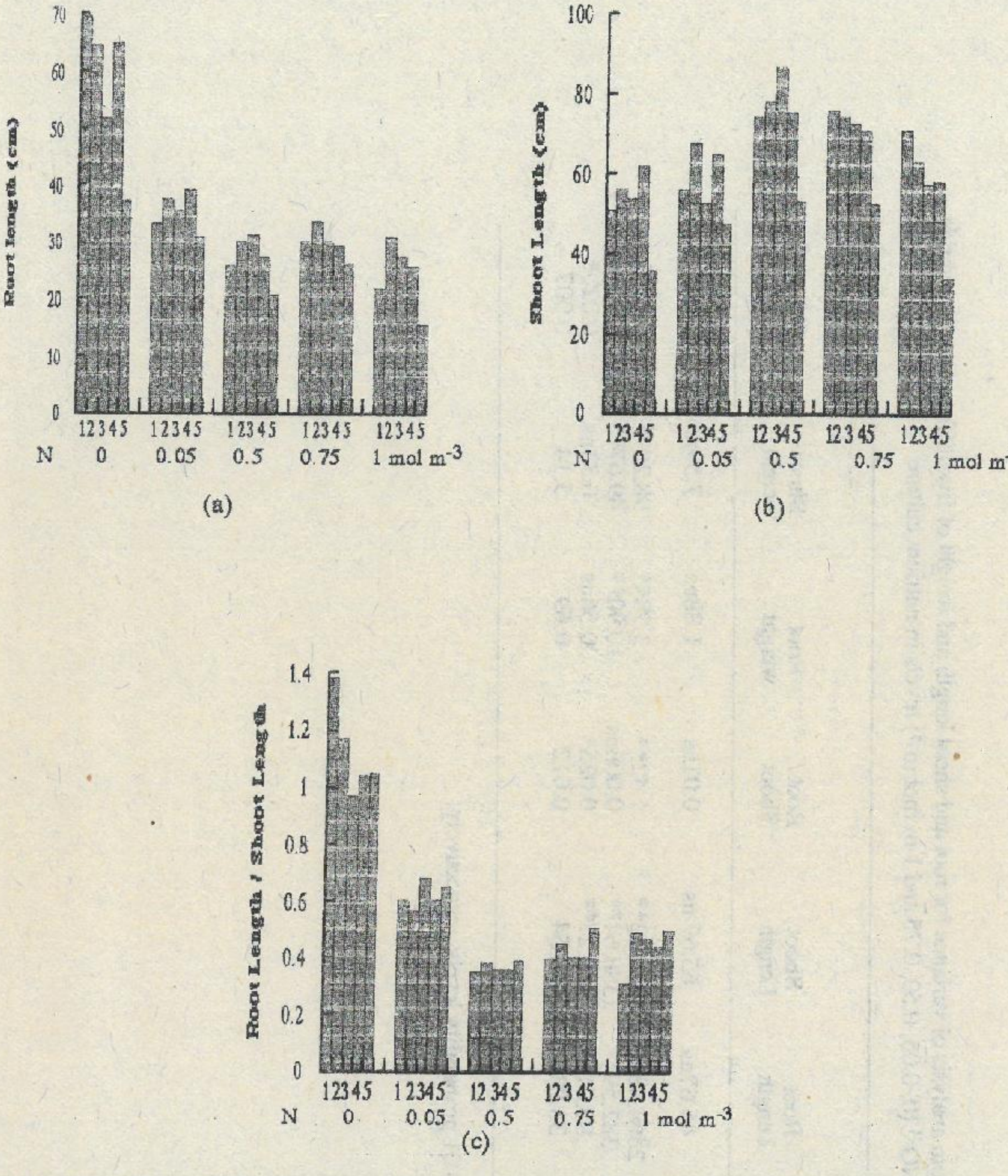

Figure 1. The effect of different nitrogen levels on root length (a), shoot length (b) and root/shoot ratios (c) of five different hybrid maize genotypes.

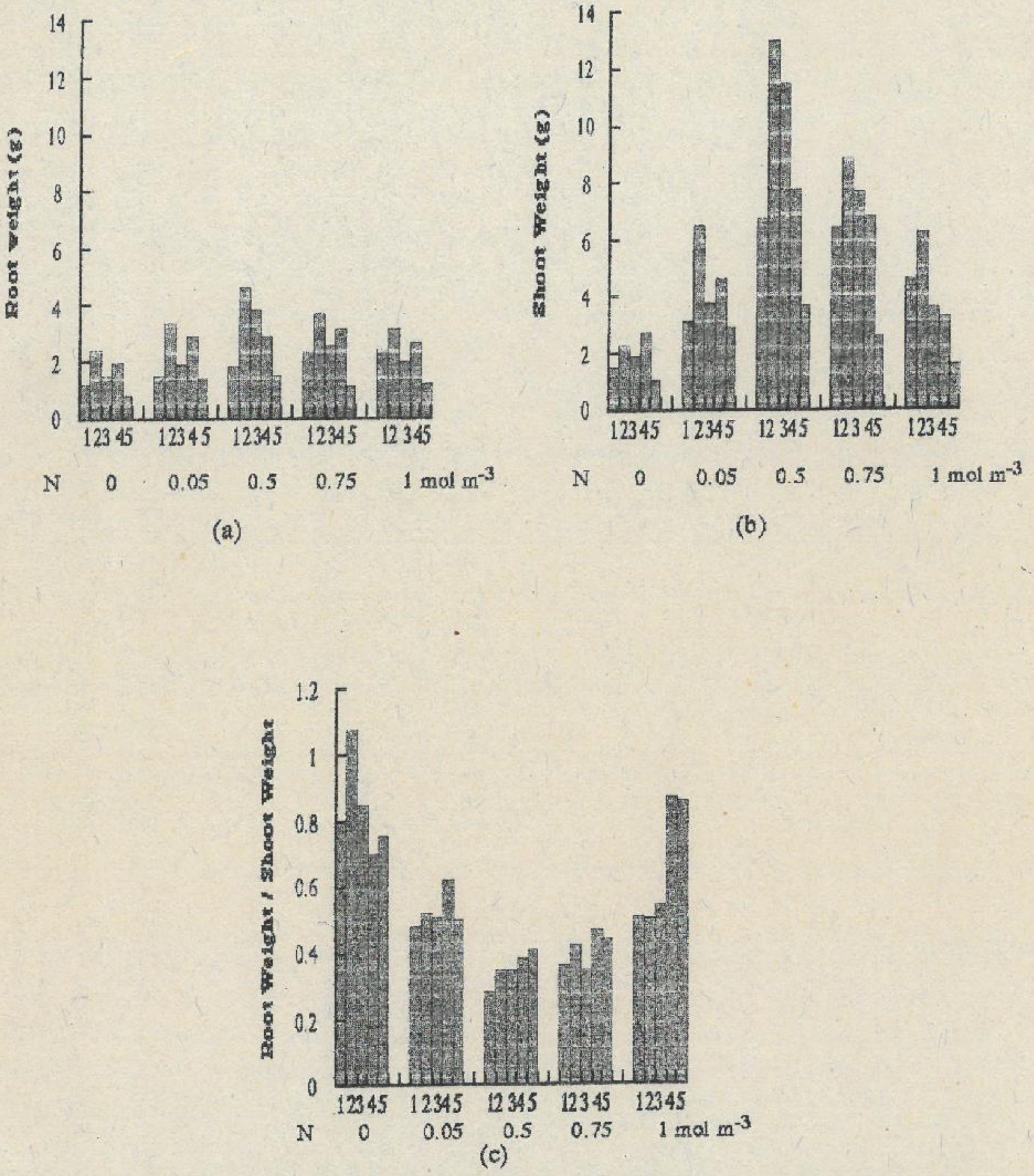

Figure 2. The effect of different nitrogen levels on root weight (a), shoot weight (b) and root/shoot ratios (c) of five different maize hybrid maize genotypes.